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A PROBABILITY MODEL AND PATROL PLANNING DEVICE FOR COUNTER-INSURGENCY OPERATIONS ON THE MEKONG RIVER

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A PROBABILITY MODEL AND PATROL PLANNING DEVICE FOR COUNTER-INSURGENCY OPERATIONS ON THE MEKONG RIVER

by

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ABSTRACT

River warfare in Viet Nam and Thailand has brought about an increased interest in river patrol techniques. To aid the river patrol in their operations a probability model is constructed that could be used for the search of large groups of boats in a sector of a river. With this model, the patrol personnel can search a portion of the boats and make predictions of the actual number of insurgent craft present, or, with intelligence information they can predict the number of insurgent craft they will expect to find in a group of boats. Also, a graphical aid is developed that should be of use to the patrol personnel in planning their patrols. By use of the graphical aid they can efficiently distribute their searching efforts in the most probable areas of insurgent activity.

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ERRATA SHEET

1. Page 7, line 5: "MeKong" vice "MaKong".

2. Page 8, line 7: "use" vice "uses".

3. Page 16, line above equation (10): substitute a comma for the period following "K".

4. Page 18, line 8: insert a comma after "boats".

5. Page 27, second line from bottom: hyphenate "process-ing" vice "proces-sing".

6. Page 27, lines 8 and 9: hyphenate "peri-ods" vice "per-iods".

7. Page 30, line 13: change "of" to "or".

8. Page 38, line 25: "chieftains" vice "chieftians".

9. Page 38, bottom line: delete apostrophe in "Thai's".

10. Page 39, lines 6 and 7: hyphenate "stretch-es" vice "stret-ches".

11. Page 44, line 3: "MeKong" vice "MaKong".

TABLE OF CONTENTS

CHAPTER		PAGE
I.	BACKGROUND	7
II.	PROBABILITY	12
III.	A PATROL PLANNING DEVICE	29
IV.	CONCLUSION	38
BIBLIOGRAPHY		40

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1.	Plot for Derivation of Confidence Interval	20
2.	80% Confidence Interval for Estimation of the Number of Insurgent Craft in a Sector of the River	21
3.	Plot of Expected Boat Densities in a Sector of the River	31
4.	Illustration of a Patrol's Expected Plan of Action	32

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CHAPTER I

BACKGROUND

In counter insurgency operations such as those presently being conducted in Viet Nam and Thailand one of the main objectives is to find and destroy the insurgents' lines of supply. In the case of Thailand the primary insurgent supply route is across the Makong River from the bordering country of Laos. It is therefore desirable to set up some type of river patrol to search out and destroy the insurgents and their craft. This paper is concerned with the patrol of the river by light motorized river boats such as those presently in use in Viet Nam.

There are many factors which must be considered before the river boat patrol can be effectively put into operation. Three factors that are of major importance are the characteristics of the river and the people living along its banks, the amount of intelligence information available on insurgent methods and activity, and a preliminary analysis of the best methods of patrolling the river.

The Mekong River forms almost the entire border between Thailand and Laos. It is well over 1000 miles in length and averages 500 yards in width but may extend to 350 or 500 yards. The river varies in width depending on the seasons. The depth of the river varies from one that would support small boats to depths that will allow almost any size craft to traverse it. As with all rivers it contains rapids and sand bars which will have their effects on the crossing points for insurgent craft. In some points along the river

there are tributaries feeding it which are directly opposite each other, making it possible for the insurgents to sail directly from inland Laos to inland Thailand.

There are villages in both countries scattered along the river and the local people use it as a source of fish for food. There is also some indication that the local populace may also uses the river for some forms of commerce. The river topography will have some effect on the density of local non-insurgent craft on the river. For instance the bottom characteristics will determine the location at which the fishing boats tend to congregate to catch the most fish. The weather will also contribute to the fishing boat density. As an example it has been found that during hot weather the fishermen prefer to fish at night when it is cooler.

Through contacts with the Thai villages much of this information can be gained and used to determine the expected boat densities at various points on the river. This will aid the patrol operations in that they will be able to predict where the boat densities will be the greatest and concentrate their patrol efforts accordingly.

To effectively get their men and supplies across the river the insurgents will try to use crossing points that are in close proximity to access routes on both sides of the river. These routes coupled with intelligence information should give points of high probability of finding the insurgents when the patrol is put into operation. Much of this type of intelligence information could be gained during

the patrol operation from the local people through the Thai personnel on the patrol force.

Our present intelligence indicates that the insurgents can be expected to use the local populace to its fullest extent in their supply operations. When possible, they will commandeer the local fishing boats for their operations and will disguise themselves and their boats to make them indistinguishable from the local craft.

The method presently used by the Thais for determining whether a boat is to be classified as an insurgent craft is to search the boat for military equipment and to question the occupants of the boat. This questioning is done by Thai personnel familiar with the people of the region and they are usually residents or past residents of the region. Their classification of the boat personnel is based on their language usage, familiarity with the area and general reaction to the questions. This technique seems to be crude at first glance, but even in the United States it is possible to determine whether a person has been in the present locality for any length of time if he is questioned by one of the local inhabitants. With this fact in mind it is doubtful if a better technique could be established. Along with these facts some other information will have to be gained on the following topics before the river patrol can be effectively put into operation.

A knowledge of the political constraints involved will have direct bearing on the river patrol methods. Some of

the more important constraints that will have to be considered are:

A. How close to the Laotian bank can the boats patrol?

B. Can all boats be searched anywhere on the river?

C. Is pursuit of a boat by fire to the Laotian bank permitted?

D. What are the political thoughts of the people on the friendly bank and how hostile are the local people on the insurgent side?

In the realm of intelligence some important information would be desirable:

A. Estimated supplies required by the insurgents already in Thailand.

B. Estimated shipping required with the given type boats to effectively carry these supplies.

With the previous information taken into account it is desirable to set up a patrol technique that will allow a most efficient use of men and patrol boats.

Due to the length of the Mekong it will have to be broken up into small sectors and a group of boats assigned to patrol a given sector. How the boats patrol the river will depend upon the river configuration and the areas designated as having a high probability of being an insurgent crossing point. If two tributaries empty into the Mekong from opposite sides of the river it would probably be desirable to station one of the patrol craft at this

point to catch all insurgent craft using this crossing; however, for long stretches of the river with many fishing boats in the sector it would probably be desirable to patrol the sector in a random fashion, randomly searching boats to determine infiltrator density. If this density proves to be sufficiently high it would be desirable to search all of the craft in the area.

It is this last situation that is analyzed in the next section. The problem can be stated as follows:

> A group of boats are present on a particular section of the river. It is desired to check a portion of the boats and determine, to some degree of confidence, the number of insurgent boats that are present.

CHAPTER II

PROBABILITY MODEL

To construct the probability model a number of assumptions were made for both the patrol technique and the insurgents' tactics. The insurgents who are trying to cross the river when the patrol craft enters the sector are assumed to somewhat randomly distribute themselves with the fishing boats and other local craft on the river. They will stay mingled with the fishing craft until they are caught or until they determine that they are in danger of being caught in large numbers.

The assumptions made for the river patrol craft are that they will use a random search technique and only search a portion of the boats to determine if there are any enemy craft in the group of boats. To use this model the patrol craft will have to work in pairs or carry sufficient personnel to facilitate handling any insurgent craft that are caught. Without this assumption the patrol craft would have to process each insurgent craft caught. This would waste valuable time and allow other insurgent craft to move out of the patrol craft's path. It is doubtful that the patrol personnel can be one hundred percent efficient in their classification procedures so it is assumed that there is a probability of detecting an insurgent boat given it is searched. To keep the model realistic it is also assumed that there is some probability of wrongly classifying a friendly boat as an insurgent craft. Corresponding to these assumptions, the following parameters are defined:

B - total boats on the river in the sector

G - total number of insurgent craft in the total number of boats, B

K - number of the boats, B, that are chosen to be searched

N - number of boats searched that are actually insurgents

F - number of insurgent boats searched that are detected

p - probability of detecting an insurgent craft given it is searched

I - total friendly boats in the total B boats, I = B-G

M - number of friendly boats checked, M = K-N

W - number of friendly boats wrongly classified as insurgents

$\tilde{p}$ - probability of wrongly classifying a friendly boat searched as insurgent

Q - total of boats classified as insurgents, Q = W≠F

With the previous assumptions and definitions, assume the parameters B, G, K, p and $\tilde{p}$ are known constants. To derive the desired probability functions the problem can be simplified to a "balls and urn" type problem but with two main differences: there is some probability, p, of being able to recognize a black ball when it is drawn; and also some probability, $\tilde{p}$, that the white balls drawn will be wrongly classified as black ones. Using this method it is desired to determine the number of balls, Q, in a sample of

size K that will be classified as black ones.

The parameters and equations obtained for the urn problem are equivalent, symbolically, to the parameters defined for the river boat problem (i.e., sample space B is equivalent to the number of boats present on the river B, etc.)

B - total number of balls in the urn

G - total number of black balls that are contained in the total number of balls, B

K - size of the sample drawn from the urn

N - number of black balls in the sample of size K

F - number of black balls of the N that are correctly classified as black balls

p - probability that a black ball will be correctly classified as a black ball when it is drawn

I - total number of white balls present in the sample space B. I=B-G

M - number of white balls in the sample of size K

W - number of white balls of M that are wrongly classified as black balls

$\tilde{p}$ - probability that a white ball drawn will be wrongly classified as a black ball

Q - total number of balls out of the sample of size K that are classified as black balls. Q=F+W

For this portion of the analysis the parameters B, G, K, p and $\tilde{p}$ are assumed to be constant. For this urn problem the sample of size K is drawn without replacement. In an urn problem of this type the probability distributions for

the number of black and white balls drawn are defined by the Hypergeometric probability law:

$$(1)\quad P[N=n] = \frac{\binom{G}{n}\binom{B-G}{K-n}}{\binom{B}{K}}$$

and

$$(2)\quad P[M=m] = \frac{\binom{B-G}{m}\binom{G}{K-m}}{\binom{B}{K}}$$

The probability distribution of successes, F, in N Bernoulli trials where there is a probability, p, of success is defined by the Binomial probability law.

$$(3)\quad P[F=f] = \binom{N}{f} p^f (1-p)^{N-f}$$

Likewise for W successes in M Binomial trials with probability p of success:

$$(4)\quad P[W=w] = \binom{M}{w} p^w (1-p)^{M-w}$$

(Here "success" means classifying a white ball as black.)

Using equations (1) and (3) and letting N be a random variable rather than a parameter:

$$(5)\quad P[F=f \mid N=n] \cdot P[N=n] = \frac{P[F=f, N=n]}{P[N=n]} \cdot P[N=n] = P[F=f, N=n]$$

Summing equation (5), over all possible values of N will give the probability function for F.

$$(6)\quad P[F=f] = \sum_{\substack{\text{all } n \\ \text{such that} \\ P[F=f \mid N=n]>0}} P[F=f, N=n]$$

With the given parameters, the values of N that satisfy the restriction on the summation are: $f \le N \le \min(K, G)$. Obviously N must be at least as great as f from the Binomial

equation (3). The upper limit on N comes from the parameters: N can be no larger than G (from the hypogenetric argument) and if the value of K is less than G then N can be no larger than K. This gives the limits on equation (7).

$$(7)\quad P[F=f] = \sum_{n=f}^{\min(K,G)} P[F=f, N=n]$$

The same reasoning is valid for the derivation and limits on equation (8).

$$(8)\quad P[W=w] = \sum_{m=w}^{\min(K,B-G)} P[W=w, M=m]$$

With these equations the probability function for Q , the number of balls that are classified as black, can be obtained. For Q= F+W and for a given value of N:

$$(9)\quad P[Q=q|N] = P[F+W=q|N] = \sum_{x=0}^{q} P[F=x|N]\, P[W=q-x|N]$$

where the first equation in the sum is equation (3) and the second is equation (4) with M=K-N (therefore making it a function of N).

To get the probability function for Q in terms of G, B, p, $\tilde{p}$ and K. equation (1) is used in the following way:

$$(10)\quad P[Q=q|G,B,K,p,\tilde{p}] = \sum_{n=0}^{\min(K,G)} P[Q=q|N=n]\, P[N=n]$$

The limits on n are determined in the same manner as for equation (7).

Now Q is in terms of the parameters and has the following form:

$$(11)\quad P[Q=q] = \sum_{n=0}^{\min(K,G)} \left\{ \left[\sum_{x=0}^{q} \binom{n}{x} p^x (1-p)^{n-x} \binom{K-n}{q-x} \tilde{p}^{q-x} (1-\tilde{p})^{K-n-q+x} \right] \frac{\binom{G}{n}\binom{B-G}{K-n}}{\binom{B}{K}} \right\}$$

(It can easily be proven that this equation reduces to the hypergeometric distribution when p=1 and $\tilde{p}=0$.)

Equation (11) is the probability density function for the number of balls that will be classified as black ones. Relating this equation back to the boat problem, equation (11) is the probability density function for the number of boats that are expected to be classified as insurgent craft given the values of B, G, p, $\tilde{p}$ and K.

With equation (11) and an estimator for G, a confidence interval can be constructed that will give the limits on G to a specified degree of confidence.

An estimator for G could be determined by the principle of maximum likelihood but the complexity of equation (11) would require a large amount of mathematical manipulation to obtain such an estimator; if one exists at all. As a first approximation to an estimator for G, assume the following:

$$(12)\quad \hat{G} = \frac{Q}{K} B$$

This is a reasonable assumption if the value of p is large and the value of $\tilde{p}$ is small. If this is not in fact true the river patrol would not be very effective anyway. The ability to tell an insurgent craft from a friendly craft with some accuracy is a requirement. As this analysis

progresses, it will be desirable to estimate the number of insurgent craft present from the value of Q, the number classified as insurgent, in order to avoid unnecessary computations on the part of the river patrol personnel.

With an estimator of the number of insurgents present, G, the following analysis from the reference by Mood and Graybill is relevant.

For the population of boats equation (11) is the density function for Q for a given value of G. Representing (11) by f(q,Q), a density can be determined for $\hat{G}$ which can be represented by f'($\hat{G}$, G). This function can be determined by the following manipulation on equation (11).

$$(13)\quad P[\hat{G}=g_1,G] = P[\tfrac{Q}{K}B=g_1,G] = P[Q=g\tfrac{K}{B},G]$$

which is equation (11) with $q = g\frac{K}{B}$

For illustration, assume that an 80% confidence interval is desired. If a value of G = G' is substituted into f' ($\hat{G}$,G) then the distribution of $\hat{G}$ is completely specified and probability statements about $\hat{G}$ can be made. For this analysis two numbers, g_1 and g_2 can be found such that:

$$(14)\quad P[\hat{G} < g_1] = \sum_{0}^{g_1} f'(\hat{G},G') = 0.1$$

$$(15)\quad P[\hat{G} > g_1] = \sum_{g_2}^{13} f'(\hat{G},G') = 0.1$$

The values of g_1 and g_2 will be dependent on the value of G' and can be written as such: $g_1(G')$ and $g_2(G')$. Then:

$$(16)\quad P[g_1(G) < \hat{G} < g_2(G)] = \sum_{g_1(G)}^{g_2(G)} f'(\hat{G},G) = 0.80$$

and $g_1(G)$ and $G_2(G)$ may be plotted against G as in Figure 1. A vertical line through any value of G' of G will intersect the two curves in points which, when projected on the G axis will give limits between which G will fall with probability 0.80.

With the curves obtained, a confidence interval for G can be constructed as follows: A number of boats are checked, Q classified as insurgent and the value of the estimator say $\hat{G}'$ is computed. A horizontal line through the point $\hat{G}'$ on the $\hat{G}$ axis (Figure 1) will intersect the two curves at points which may be projected on the G axis and labeled G_1 and G_2 as in the figure. These two numbers define the confidence interval:

(17) $P[G_2 \leq G \leq G_1] = 0.80$

The argument for the proof of this statement is made by assuming that the sampling was made from a population that had G' as the value of G. The probability that the estimate G will fall between $g_1(G')$ and $g_2(G')$ is 0.80. If the estimate does fall within these limits, then the horizontal line will cut the vertical line through G' at some point between the curves, and the corresponding interval (G_2,G_1) will cover G'. If the estimates do not fall between $g_1(G')$ and $g_2(G')$, the horizontal line does not cut the vertical line between the curves, and the corresponding interval (G_2,G_1) does not cover G. It follows, therefore, that the probability is exactly 0.80 that an interval (G_2,G_1) constructed by this method will cover G'.

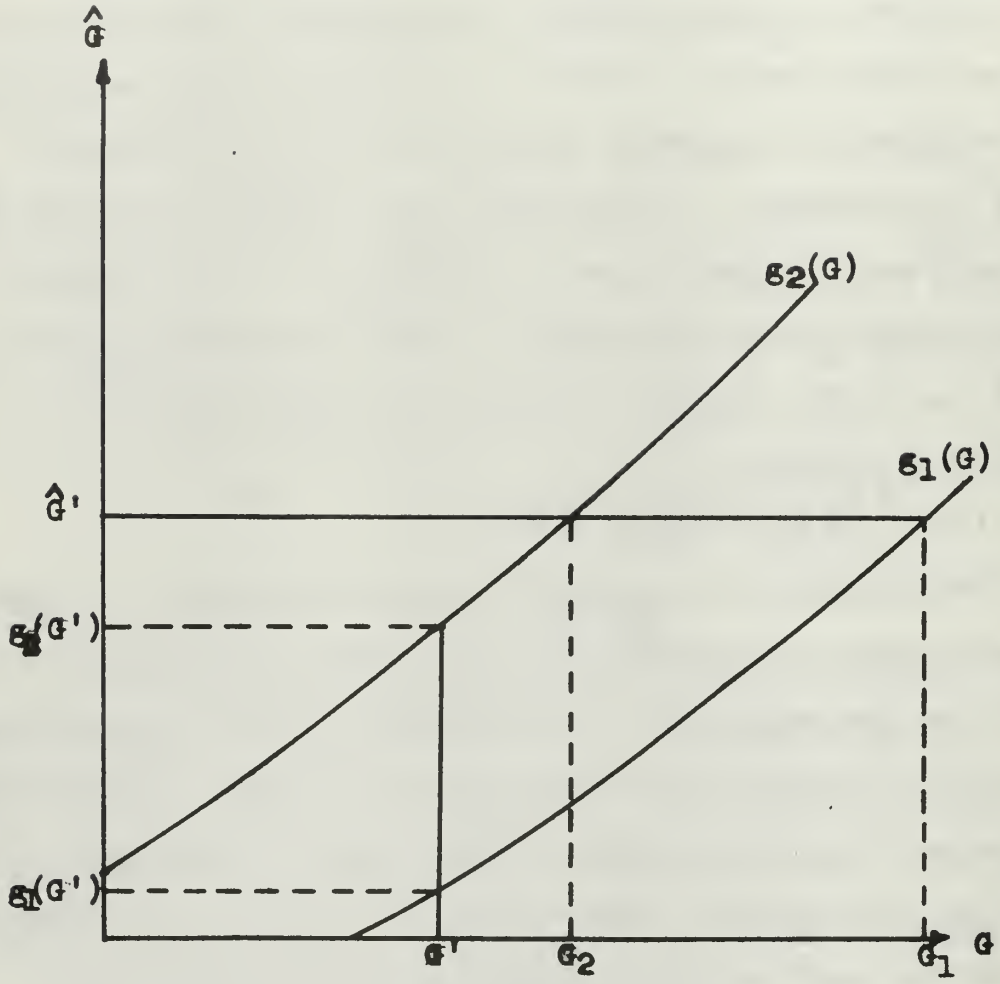
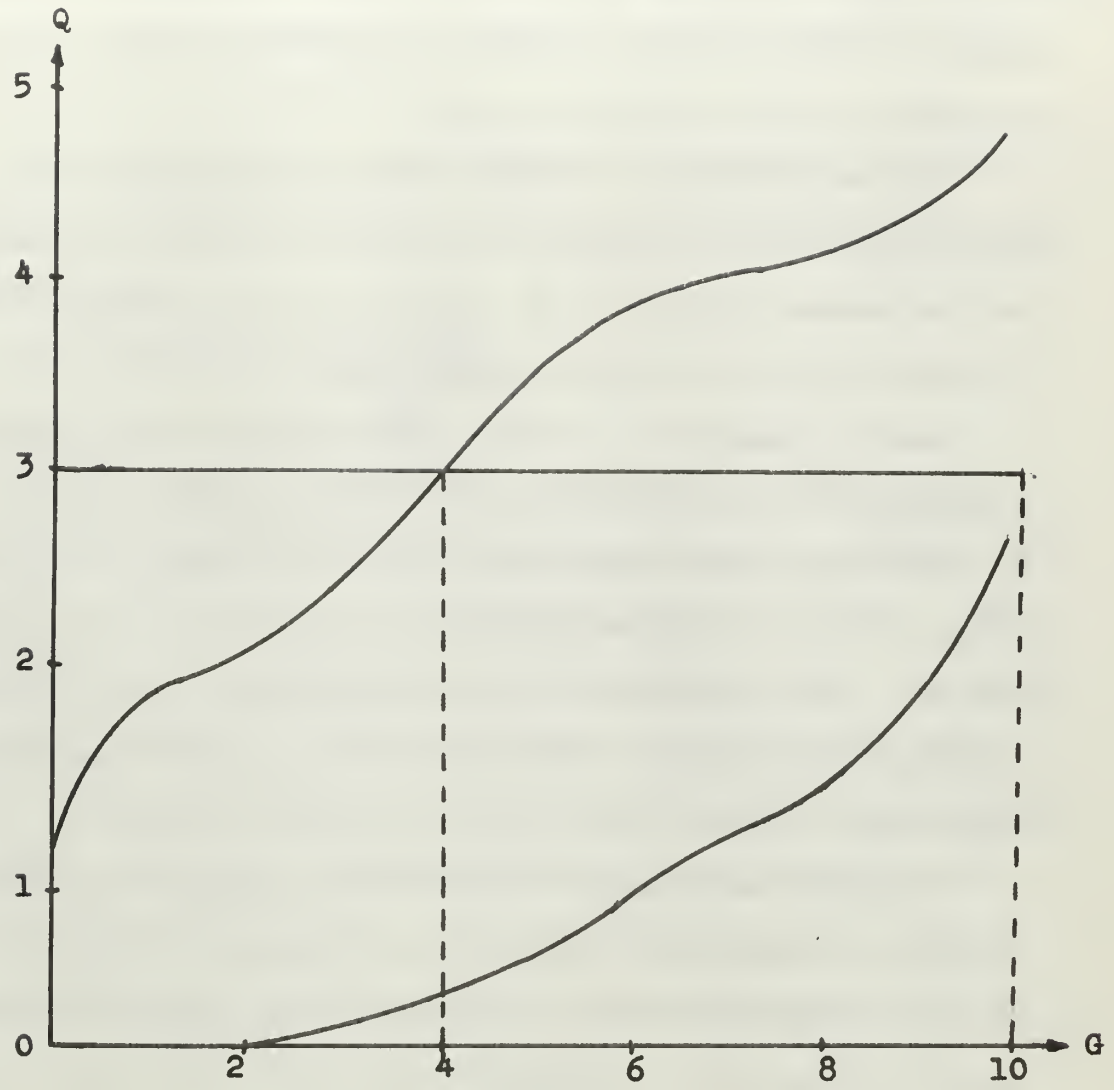


FIGURE.1

Plot for Derivation of Confidence Interval



Parameters: B=10
p=0.8
p=0.1
k=5

FIGURE 2

80% Confidence Interval for Estimation of the Number of Insurgent Craft in a Sector of the River

In actuality these curves would be a set of points due to the discreteness of the density functions. However, for the accuracy desired in the use of the curves the discrete points can be plotted and the points connected to obtain estimates of the values desired.

For simplicity of use by the river personnel the curves can be plotted as Q versus G to avoid the labor involved in the conversion from Q to $\hat{G}$. Figure 2 is an example of one of these curves for the parameters given.

As an example of its use suppose that the parameters correspond to an actual situation and Q is determined to be 3. Then the patrol personnel can be 80% confident that the actual number of insurgent craft on the sector is between 4 and 10. This indicates that the majority of the boats would probably be insurgent craft and that the patrol would probably want to search the rest of the boats present.

As more intelligence and reconnaissance information is obtained it should be possible to estimate the amount of supplies required by the insurgents, the number of boats that would be required to transport them, and the possible crossing points on the river for these supplies. These estimates, coupled with the assumptions that the insurgents will try to use river crossing points where the high density of river boats will cover their movements, permit estimates to be made of the number of insurgent boats that will be present in any sector of the river.

With knowledge of the hours during the day when the fishing craft are in their highest densities and also the

length of time that they remain at these densities, the previous information will allow an estimate to be made of the number of insurgent craft on the river at any instant of time. Let this expected number of insurgent craft present at any instant be represented by h.

The distribution of the number of insurgent boats expected to be present can be represented by the Poisson probability law.

$$(18)\quad P[G=g] = \frac{e^{-h}(h)^g}{g!}$$

If the expected number of insurgents per unit area of the sector is μ and the area of the sector is t, then $h=\mu t$ is of the form that fits the Poisson probability law. This is not exactly representative of the distribution of G since it is defined for $0 \leq G \leq \infty$ whereas in this context here it has an upper limit of B. This is not of too much concern since the number of insurgent craft in most instances will be much, much less than B. The approximation will then be valid because for values of $g \ll B$ the probabilities will be so small as to be of no consequence.

With this distribution function and the probability equations previously derived a set of data could be compiled for determining an estimate of the values of G given a value of Q. This would result from the application of Bayes Theorem to the derived equations. An equation for the probability that a value of G will result from a given value of Q will have the form:

$$(19)\quad P[G=g \mid Q=q_0] = \frac{P[Q=q_0 \mid G=g]\ P[G=g]}{\sum_{g'=0}^{K} P[Q=q_0 \mid G=g']\ P[G=g']}$$

Where $P[Q=q \mid G=g]$ is in actuality equation (11) with parameters B, G, K, p and $\tilde{p}$.

Tables of probabilities defined by equation (19) could be computed for a range of values of G, B, K, p, $\tilde{p}$ and h. From these tables expected values of G could be obtained for values of Q which would be used by the river patrol in their searches. These tables would be of value to the river patrol when large sectors of the river contained many groups of boats. The patrol craft could search a number K of the total B boats in any group, determine a number of Q boats classified as insurgent (with the assumed values of p and $\tilde{p}$) and from the predicted values of h could estimate that there was a number of insurgents present. If this number of insurgents was less than what was expected, the patrol could possibly better utilize their time searching another group of boats in the sector, while a larger value could mean that there is more insurgent traffic than estimated.

With this a priori knowledge on the number of insurgent craft in a group of boats another piece of information can be computed before the patrol starts. For this information another probability function is derived:

$$(20)\quad P[Q=q_0] = \sum_{g=0}^{B} P[Q=q_0 \mid G=g]\ P[G=g]$$

given B, h, K, p and $\tilde{p}$.

To see how this equation can be used, assume a value for each of the parameters, B, K, p, $\tilde{p}$ and h. With these parameters defined we can find a range of values for Q such that $P[q_1 \leq Q \leq q_2] = .9$ while choosing the smallest interval (q_1, q_2) that yields the .9 probability.

The .9 probability constraint is the level of confidence that is desired on the range of Q. With the .9 example the patrol personnel can be 90% confident of obtaining a value of Q in the interval (q_1,q_2) for the given parameters. The .9 level is not necessarily the optimum level and the patrol personnel may choose a lower or higher one. The tables can be computed for various levels and the patrol personnel can use their own discretion in choosing the level to fit the situation.

By assigning different values to K, while holding the other parameters constant, different intervals, (q_1,q_2), can be obtained for the .9 probability constraint.

If the same procedure is repeated for ranges of the parameters B, p, $\tilde{p}$ and h, a set of tables can be constructed which can be used in the following way. The values of B and h can be predicted for an area along the river. The patrol personnel can go to the tables described and for various values of K can determine the range of values of q_1 and q_2 that would result for a desired level of confidence.

The value of K will have to be chosen with consideration for the length of time the patrol desires to spend searching any one group of boats. It would also be desirable to find a reasonable range on Q. The interval (q_1,q_2) should be

large enough so as to contain a few values of Q rather than just one or two points.

With these established values of K, q_1 and q_2 the patrol can then search the K boats in the area where the predictions were made and will classify a number of the boats as insurgents. If this number is within the predicted range then the patrol can assume their prediction of the expected number of insurgent craft, h, was correct. If the number of boats classified as insurgent craft is less than the number predicted then the patrol can concentrate their patrol in another area of the river. If the number is larger than what was expected then the patrol can assume that there is a possibility of a greater number of insurgents being present. At this point the confidence curves like those of Figure 2 would be of value.

The results of this analysis are used in the suggested patrol technique discussed in the next section of this paper.

The probability equations in the preceeding paragraphs are all discrete functions which makes them easily adaptable to computer computation. Should they be a desired aid to the river patrol, a computer program can be quickly written which will generate the desired tables and graphs.

One of the advantages of this model is that it can easily be adapted for night patrol as well as daytime patrol. The application of the model to night patrol is contingent upon the river craft having radar. This will make it possible to have a group of targets presented from which the random selection of boats to be searched can be made. This random

selection procedure may have shortcomings if the patrol craft personnel have the ability to pick out possible insurgent craft by visual means. If this is true then the random search technique will have limited value. However, for night operations where radar is available the model should be quite applicable.

This model is obviously not applicable on long stretches of the river where very few boats are present or during periods when the fishing craft are not out en masse.

The probability model which is developed in the preceeding pages was constructed after studying an informal paper by D. J. Kaplan which is concerned with the same problem. There are some major differences in Kaplan's approach and the problem as presented here. Kaplan starts his development by assuming that the insurgent craft will be composed of two types: those that are always insurgents and those that are sometimes insurgents or sometimes friendly. From this he develops the probability distribution function for the number of insurgents present in a given sector. Kaplan also uses a probability of detecting an insurgent if it is in fact searched but does not consider the possibility of wrongly classifying a friendly boat as an insurgent craft. This was believed to be a factor of importance since many friendly boats in the Viet Nam river patrols are designated as insurgent craft only to be released after further processing. These differences in the two types of approach to the

problem result in essentially the same type of probability model, but it is hoped that this paper has a more realistic and general approach to the formulation of equations.

CHAPTER III

A PATROL PLANNING DEVICE

Using the assumptions made in the preceding sections a plot can be made showing the expected fishing boat density at various times of the day in a given sector. From this type of plot a method of planning a patrol will be devised which will be flexible and yet result in an efficient search. For purposes of illustration only one half of a sector will be used and the total time will be that of an assumed eight hour patrol. Plotting the length of the patrol area on the vertical axis (10 miles for illustration) and the time on the horizontal axis as shown in Figure 3 the density at various points along the river can be plotted as a function of time. These boat densities are shown in their respective locations along the river in their expected time frame. For example, the 30 boat density area is expected to build up to its full force at about 0220 and remain in force until about 0645. Using intelligence information the expected number of insurgent craft can be estimated and noted along with the other information. This information can be noted as in Figure 3 in the 30 boat density area (10 insurgent craft are expected to be present at any time). The notes on fishing grounds and villages are noted to show reasons for the boat densities.

Using the previously developed probability functions the patrol personnel can compute a number of boats to search and a range of values for the number of insurgent craft they should detect for a desired confidence. Hypothetical values

of these parameters are also included in Figure 4.

For the derivation of this patrol technique assume that the patrol craft can travel up the river at 15 knots and down the river at 20 knots. Also assume that it will require 15 minutes from the time a search is commenced on one boat until the search is commenced on another boat.

If the patrol is to search the 10 insurgents in the 30 boat density area it will have to spend 2.5 hours ($\frac{10 \text{ boats}}{4 \text{ searched/hour}}$) in the area and in the 25 boat density 1.75 hours are required for searching the 7 boats.

On Figure 4 (a reproduction of Figure 3) is plotted the vector representing the upriver speed of the boat. The patrol craft can travel 15 miles in one hour of 7.5 miles in one half hour. Drawing a line through the patrol departure point and the point of time, 0030, and the distance from base, 7.5 miles, will result in the velocity vector for the patrol craft traveling up stream. Likewise, drawing a line through the point labeled "required patrol return time" and the point of 10 miles and 0730 hours will give the down stream velocity vector. By drawing lines parallel to these two vectors the patrol personnel will be able to determine how far they can travel upstream or downstream in a given time. For instance, the patrol craft can leave the base camp at time 0000 and arrive at the 10 boat density area in a little over thirty minutes.

To see how this graphical procedure will be used, assume that it is desired to commence a patrol at 0000 traveling to

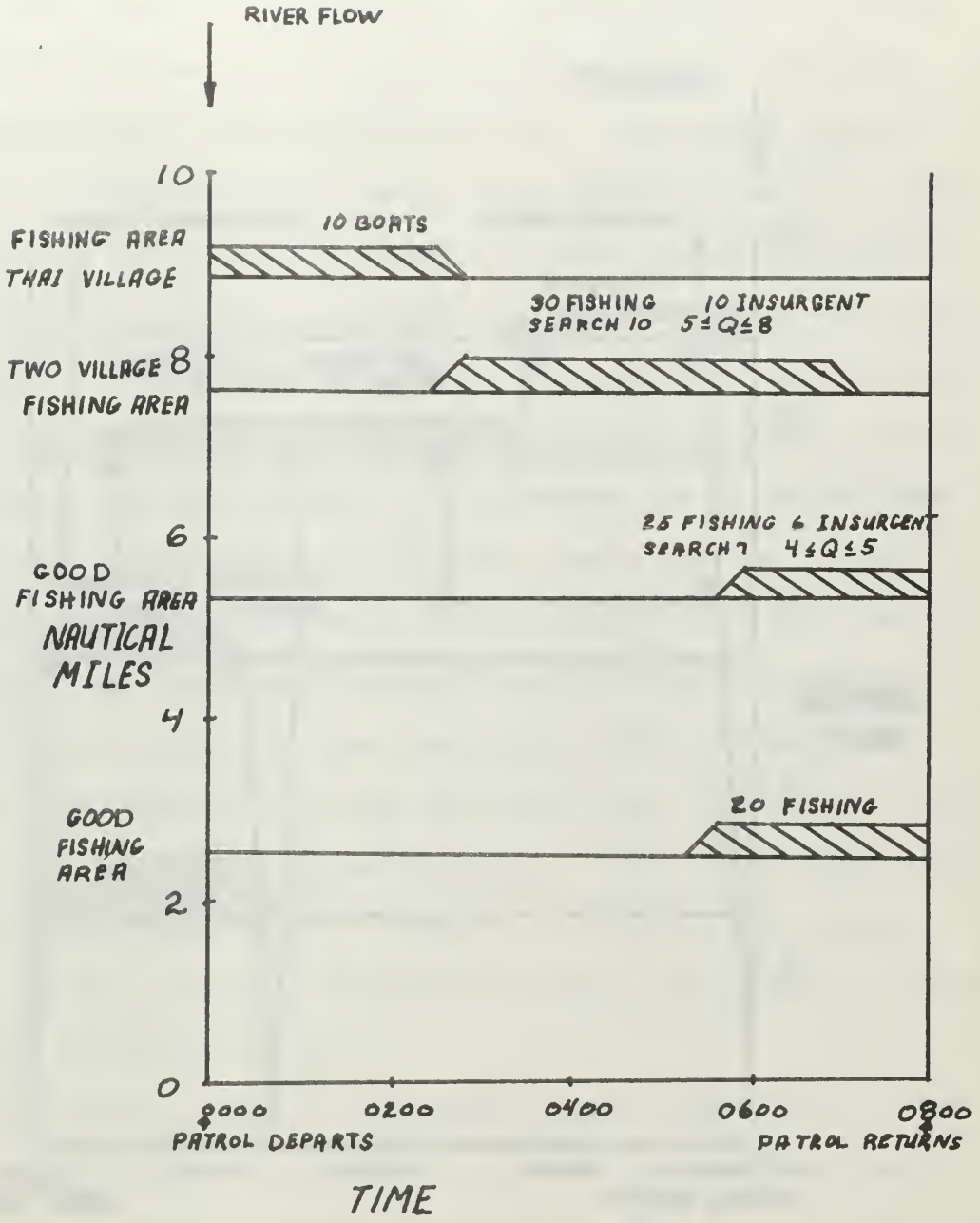


FIGURE 3

Plot of Expected Boat Densities in a Sector of the River

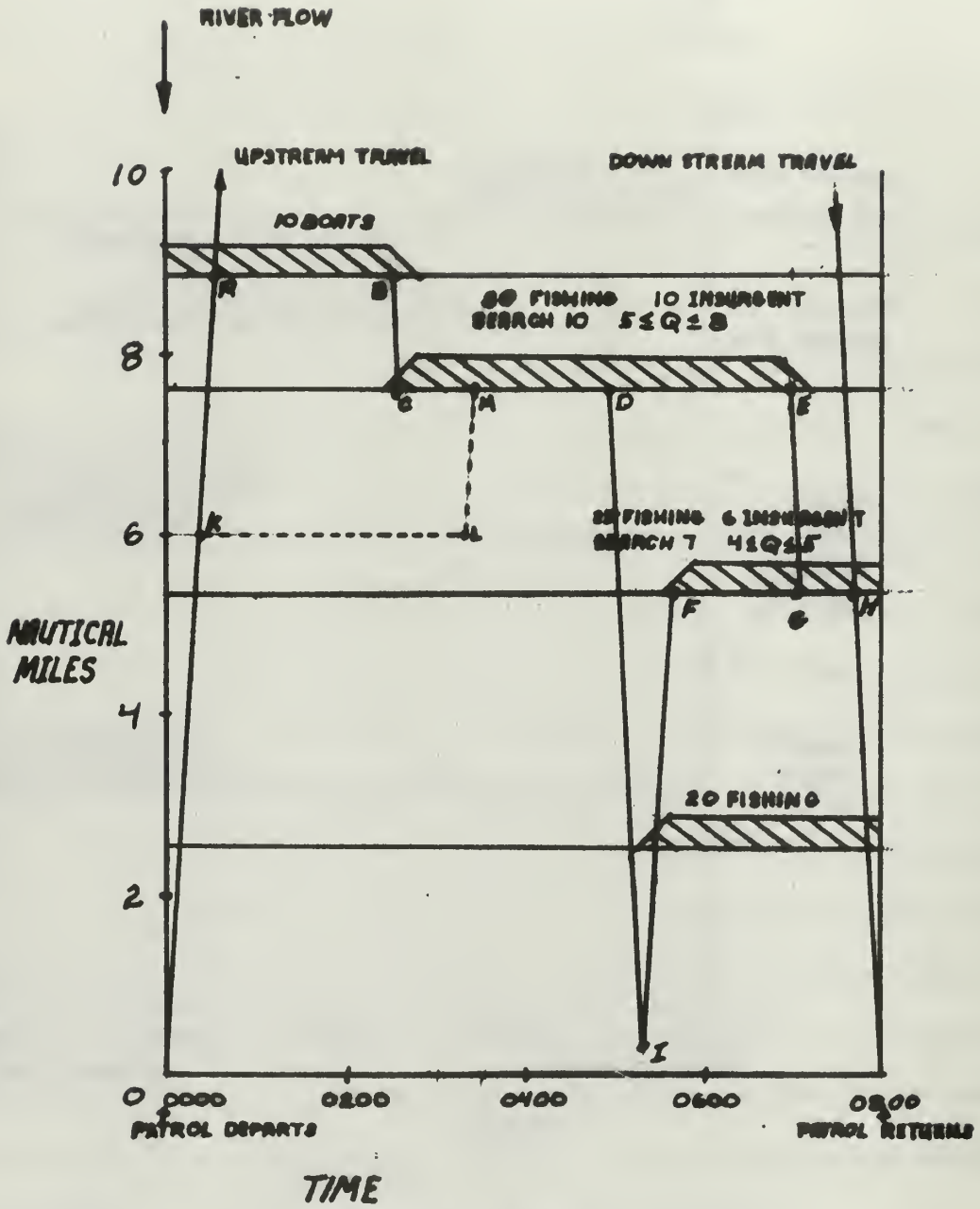


FIGURE 4

Illustration of a Patrol's Plan of Action

point A (in the 10 boat density area) of Figure 4. They decide to search a portion of the boats until the craft build up in the 30 boat density area. They want to search boats until about 0220 (Point B) and then travel to the 30 boat density area (Point C). The travel from B to C is represented by a line parallel to the "downstream travel" vector. In this group of boats they want to search at least ten to find out if their estimate of the insurgent traffic was correct. The time required for this search is laid out along the respective time axis and is from point C to point D. At the end of this search period (point D), the patrol craft have two options open: the search can be terminated if the expected number of insurgent craft was not present or can continue to search if their expectations were met or exceeded. If the search is continued they can search out to the time at point E when the boats start to disperse. Should this option be chosen they can leave the 30 boat sector at the time represented by point E and travel (parallel to the "downstream travel" vector) to point G and search until the time of point H where they must start back to base in order to arrive by 0800.

Should the number of insurgent craft expected not show themselves at point D the patrol could travel downstream in a routine search and then turn around and come back into the 25 boat sector to gain an element of surprise. Assuming they would choose this option the plot could be simple constructed as follows:

A. Draw a line from the 0540 point at F parallel to the "upstream travel" line. This will represent the patrol's return to the sector.

B. Draw a line from point D parallel to the "downstream" travel line until it crosses the line drawn from F. This is the point I.

The patrol craft now travel from point D to point I to point F where it can search in the 25 boat area until the time of point H where it must start the return trip to its base in order to arrive by 0800.

Figure 4 is now a representation of the planned patrol, with the options that can be chosen according to the situation. Note that the option including the D, I, F sequence has allowed for show of force by the patrol merely being present on the river (even though no boats are expected to be encountered). This segment also provides for an element of surprise by passing through the 25 boat sector and then returning to it at a later time for the actual search.

The plot of the planned patrol can be modified as the patrol progresses. For an illustration consider the patrol as previously planned. The patrol craft follow the plan until they are 6 miles from their base (point K, Figure 4). At this point they encounter ten boats. No boats were expected in the area so it is decided to search all ten of the craft. This takes the patrol up to the time at point L. Using the upstream velocity vector, the best option is in the 30 boat density area via the line LM. The time of arrival in this area would be represented by point M. The

remainder of the patrol could then be carried out along one of the optional tracks. The KLM sequence is shown to illustrate how the patrol plot can be altered to adapt to unexpected situations while the patrol is in operation.

The entire procedure can be summarized as follows:

1. Set up axes with the length of the sector marked on the vertical axis and the time of the patrol in hours along the horizontal axis.
2. Plot in the expected boat density at their various points along the vertical axis and in the time frame when they are expected to occur.
3. Write in the number of insurgent craft expected to be in the areas at any time.
4. Plot in the two vectors that represent the velocity that can be made good upstream and downstream.

    To plot the upstream vector, find the time it will take for the patrol craft to travel the full length of the assigned sector. Make a point at the end of the sector and connect this point with the base camp zero time point. This forms the upstream vector. For the downstream vector, again compute the time it would take the patrol craft to travel the full length of the sector. Subtract this time from the total patrol time and make a

point at this time and at the end of the sector. Connecting this point and the base camp-end of patrol time forms the downstream velocity vector.

Using parallel rulers these velocities can be carried over to any point on the plot when needed.

5. Using the tables described determine a number of boats to be searched in each area to determine if the number of insurgent craft expected are present. Also determine the time required to search this number of boats. Should no information be available on the number of insurgent craft expected to be in the areas, a portion of the boats can be searched. The time in the area can then be computed from the number of boats to be searched and the estimated search time per boat.
6. By trial and error set up a search pattern (using the velocity vectors) that will allow the required number of boats to be searched or a pattern that will at least let the patrol spend the longest time in the expected areas of high insurgent density. Should more or less time be required in any area the number of boats to be searched can be modified and new values taken from the tables.

The plots can be modified as the patrol meets different situations. If boats are found where none are expected and a search of some of them is desired, the plots can be changed to account for the time spent searching these boats.

This search aid, though simple in concept, should be of some value to a patrol of this type. It allows the personnel to have some plan of action before they start the patrol, it can be modified as the patrol progresses and the possible options can be quickly checked out to see which will result in the best search possibilities.

CHAPTER IV

CONCLUSION

The probability model and graphical patrol planning device were designed to supply useful information to the river patrols in their daily counter-insurgency operations.

It is believed that the most useful information that can be obtained from the probability model will be in the form of the confidence intervals as in Figure 1. These curves do not require any intelligence information for their use. The only requirements are the two probabilities (p and $\tilde{p}$) that describe the patrol personnel's ability to discriminate between an insurgent and friendly boat in their search procedures. If there are numerous groups of boats on the river the patrol can search a few boats out of each group. If they classify some of the boats searched as insurgents, they can then use the confidence curves to estimate the total number of insurgent craft in the group. The decision can then be made to continue the search in the present area or move on to another group of boats that may contain more insurgent craft.

The remaining probability equations require some intelligence information on the number of insurgent boats that are expected to be present in a sector. This intelligence information has been difficult to obtain in Viet Nam. The Thais, on the other hand, have been able to obtain information on the movement of insurgent men and material from the village chieftians in their country. This part of the probability model would therefore be of more use to the Thai's

than to our forces in Viet Nam.

The simplicity of the graphical aid and the information it can contain make it applicable not only to the river patrol but to other patrol operations. For instance, the State Police patrol the highways in much the same manner as the river boats patrol the river. There will be stretches of the highway that will have varying densities of traffic at different hours of the day. These densities can be plotted as were the boat densities and the officers could graphically determine their arrival times, and length of time to be present in one of the stretches of the highway. They would also have the option of changing their schedule as accidents occurred, arrests were made or aid was rendered to motorists.

At the time of this writing very little analysis had been done on the river patrol problem. The only available paper was the one by D. J. Kaplan. If this paper does nothing more than create an interest in the subject, it will have been worth the time and effort.

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13. ABSTRACT

River warfare in Viet Nam and Thailand has brought about an increased interest in river patrol techniques. To aid the river patrol in their operations a probability model is constructed that could be used for the search of large groups of boats in a sector of a river. With this model the patrol personnel can search a portion of the boats and make predictions of the actual number of insurgent craft present, or, with intelligence information they can predict the number of insurgent craft they will expect to find in a group of boats. Also, a graphical aid is developed that should be of use to the patrol personnel in planning their patrols. By use of the graphical aid they can efficiently distribute their searching efforts in the most probable areas of insurgent activity.

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